Color temperature

From Wikipedia, the free encyclopedia
(Redirected from White balance)

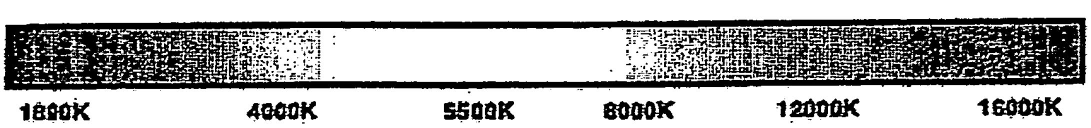
"White light" is commonly described by its **color temperature**. A traditional incandescent light source's color temperature is determined by comparing its hue with a theoretical, heated black-body radiator. The lamp's color temperature is the temperature in kelvins at which the heated black-body radiator matches the hue of the lamp.

Contents

Categorizing different lighting

Because it is the standard against which other light sources are compared, the color temperature of a black-body radiator is equal to its surface temperature in kelvins, using the temperature scale named after the 19th-century British physicist William Thomson, 1st Baron Kelvin. (Note: it should not be construed that the *color* temperature refers to the *thermal* temperature of anything other than the black-body radiator.) An incandescent light is very close to being a black-body radiator. However, many other light sources, such as fluorescent lamps, do not emit radiation in the form of a black-body curve, and are assigned what is known as a correlated color temperature (CCT), which is the color temperature of a black body which most closely matches the lamp's light emission curve. Because such an approximation is not required for incandescent light, the CCT for an incandescent light is simply its unadjusted kelvin value derived from the comparison to a heated black-body radiator.

As the sun crosses the sky, it may appear to be red, orange, yellow, white, or blue, depending on position. The changing colors of the sun and sky as the day passes also match colors produced by a black-body radiator at certain temperatures in kelvins.



[Note this diagram is only a symbolic-representation; the colors shown have not been calculated with any

colorimetric accuracy. Here's a colorimetrically accurate diagram. (http://www.techmind.org/colour/coltemp.html)]

Some common examples:

- 1200 K: a candle
- 2800 K: tungsten lamp (ordinary household bulb), sunrise and sunset
- 3000 K: studio lamps, photofloods,
- 5000 K: electronic flash, average daylight. A designation of D50 stands for "Daylight 5000K" and is the most common standard for professional light booths for photography, graphic arts, and other purposes.
- 6000 K: bright midday sun
- 7000 K: lightly overcast sky
- 8000 K: hazy sky
- 10,000 K: heavily overcast sky

From these observations, it becomes clear that blue is the "hotter" color, while red is actually the "cooler" color. This is the exact opposite of the associations both colors have taken on, with "red" as "hot", and "blue" as "cold". The traditional associations come from a variety of sources, such as the fact that water and ice reflect the color of daylight, making them appear blue, and frostbitten flesh often appears blue. Plus, as is well known, metals heated begin to glow red, and fire is reddish. But the redness of these heat sources comes from precisely the fact that red is the *coolest* of the visible colors: the first color emitted as heat increases. A proof of this is that while incandescent bulbs glow a reddish to yellowish color throughout their lifetimes; when one blows out, the flash of light is noticebly bluish! The filament is hotter when it burns out (as evidenced by the scorch mark often left on the glass)!

"Color temperature" is sometimes used loosely to mean "white balance" or "white point". Notice that color temperature has only one degree of freedom, whereas white balance has two (R-Y and B-Y).

In photography, an alternative numerical measure used is the mired. Color temperatures and mireds are convertible to each other via a simple formula (see the mired page for details of the computations, and the reasons for the use of the alternative unit).

Color temperature applications

Film photography

Film sometimes exaggerates the color of the light. An object that appears to the naked eye to be under white light may turn out looking very blue or orange in a photograph. The color balance may need to be corrected while shooting to achieve a neutral color print.

Film is made for specific light sources (most commonly daylight film and tungsten film), and used properly, will create a neutral color print. Matching the color sensitivity of the film to the color temperature of the light source is one way to balance color. If tungsten film is used while photographing indoors with incandescent lamps, the yellowish-orange light of the tungsten [incandescent] bulbs will appear as white (5500k) in the photograph.

Filters on a camera lens, or color gels over the light source(s) may also be used to correct color balance. When shooting with a bluish light (high temperature) source such as an overcast day, in the shade, in window light or if using tungsten film with white or blue light, a yellowish-orange filter will correct this. For shooting with daylight film under warmer (low temperature) light sources such as sunsets, candle light or tungsten lighting, a bluish (e.g. #80A) filter may be used.

Fluorescent light varies in color and may be harder to correct for. Because it is often greenish, a reddish filter might correct it, though this could take some trial and error.

If there is more than one light source with varied color temperatures, gels (placed over each light source) in conjuction with daylight film is the best way to balance the color.

Desktop publishing

In the desktop publishing industry, it is important to know your monitor's color temperature. Color matching software, such as ColorSync will measure your monitor's color temperature and then adjust your monitor's settings accordingly. This enables on-screen color to more closely match printed color. Common monitor color temperatures are as follows:

5000K (D50), 5500K (D55), 6500K (D65), 7500K (D75) and 9300K.

Designations such as D50 are used to classify color temperatures of light tables and viewing booths. When viewing a color slide at a light table, it is important that the light be balanced properly so the colors are not shifted towards the red or blue.

General computer-users should set their PC monitor color-temperature to "sRGB" or "6500K", as this is what digital cameras, web graphics, and DVDs etc are normally designed for. Indeed the sRGB standard stipulates (among other things) a 6500K display whitepoint.

TV, video, and digital still cameras

The NTSC and PAL TV norms call for a compliant TV screen to display an electrically "black-and-white" signal (minimal color saturation) at a color temperature of 6500K. On many actual sets however, especially older and/or cheaper ones, there is a very noticeable deviation from this requirement of the standard.

Most video and digital still cameras can adjust for color temperature by zooming into a white object and setting the white balance (telling the camera "this object is white"); the camera then shows true white as white and adjusts all the other colors accordingly. White-balancing is necessary especially indoors under fluorescent lighting and when moving the camera from one lighting situation to another. The setting called "Auto white balance" is not recommended for optimum quality video or stills.

Artistic application via control of color temperature

Experimentation with color temperature is obvious in many Stanley Kubrick films; for instance in *Eyes Wide Shut* the light coming in from a window was almost always conspicuously blue, whereas the light from lamps on end tables was fairly orange. Indoor lights typically give off a yellow hue; fluorescent and natural lighting tends to be more blue.

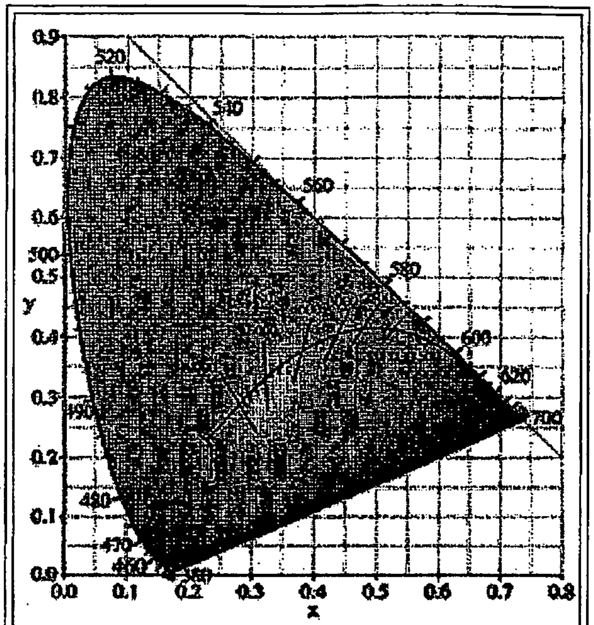
The house above appears a light cream during the midday, but seems a bluish white here in the dim light before full sunrise. Note the different color temperature of the sunrise in the background.

Video camera operators can also white-balance objects which aren't white, downplaying the color of the object used for white-balancing. For instance, they can bring more warmth into a picture by white-balancing off something light blue, such as faded blue denim; in this way white-balancing can serve in place of a filter or lighting gel when those aren't available.

Cinematographers do not "white balance" in the same way as video camera operators: they can use techniques such as filters, choice of film stock, pre-flashing, and after shooting, color grading (both by exposure at the labs, and also digitally, where digital film processes are used). Cinematographers also work closely with set designers and lighting crews to achieve their desired effects.

Correlated color temperature

The Kelvin system for lamp description works well for an incandescent light bulb. Since these lamps are very nearly black body radiators, their chromaticity coordinates land directly on the Planckian locus in the CIExy color space. Fluorescent lighting is not incandescent and presents a new challenge. Fluorescent lamps are made using myriad combinations of phosphors and gases. The illumination that they produce is almost never described by a point in color space which lies on the Planckian locus.



CIE (1931) xy chromaticity diagram including the Planckian locus, with temperatures indicated. Wavelengths of monochromatic light are shown in blue. The lines crossing the Planckian locus are lines of constant correlated color temperature.

The question then becomes how to describe the quality of light from a fluorescent lamp. The method used is called the "correlated color temperature", which a method for assigning a color temperature to a color near, but not on, the Planckian locus. The above plot shows lines crossing the Planckian locus for which the correlated color temperature is the same. Nevertheless, the colors are not the same, and the method gives only an approximate specification of a particular color. Due to this shortcoming, the rated CCT of any fluorescent tube does not completely specify its color.

To be more precise: A number of color spaces have been developed in which the difference between two colors may be estimated by the distance between them on a chromaticity diagram. These include the 1960 CIELuv (which is now outdated) and the 1976 CIELu'v' and CIELab spaces. On a chromaticity diagram for which distances specify color distances, the best estimate of the color temperature of any point will be the color temperature of the point on the Planckian locus closest to that point. Although it is outdated, the CIE specifies distances in the 1960 CIELuv chromaticity space to define correlated color temperature.

Photographers often use color temperature meters. Color temperature meters by design read only two regions along the visible spectrum (red & blue) or some expensive ones read three regions (Red, Green & Blue). They are almost useless under fluorescent light. There are general guidelines and some specific filters recommended to obtain optimum quality under such frustrating circumstances.

Color rendering index

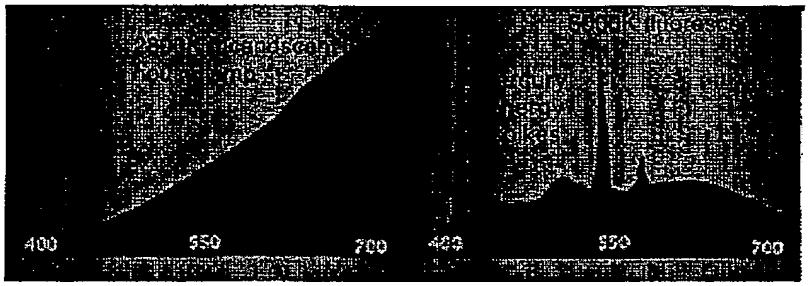
Main article: Color rendering index

The CIE developed a newer model for describing and rating light sources, called the color rendering index, which is a mathematical formula describing how well a light source's illumination of eight sample patches compares to the illumination provided by a reference source. The index provides a number up to 100 for ideal light.

Spectral power distribution plot

The spectral power distributions provided by many manufacturers may have been produced using 10 nanometre increments or more on their spectroradiometer. The result is what would seem to be a smoother (fuller spectrum)

power distribution than the lamp actually has. 2nm increments are mandatory for taking measurements of fluorescent lights. Here is an example of just how different an incandescent lamp's SPD graphs compared to a fluorescent lamp:



Recommendations for those without the expensive equipment

Only those with expensive spectrophotometers and spectroradiometers can obtain accurate data. Those without these tools should take the time to review the lamp's specifications, and if they seem good, then the eyes are one's best tool.

New mathematical indices are being proposed which look hopeful. There are at least 3 new ways to categorize lamps more accurately. They are not in use as of yet, but they look promising. One is referred to as the color rendering capacity (CRC).

References

1. Berns, Roy S. (2000). *Billmeyer and Saltzman's Principles of Color Technology*, 3rd edition, New York: Wiley. ISBN 0-471-19459-X.
2. Stroebel, Leslie; John Compton; Ira Current; Richard Zakia (2000). *Basic Photographic Materials and Processes*, 2nd edition, Boston: Focal Press. ISBN 0-240-80405-8.
3. Wyszecki, Günther; W. S. Stiles (1982). *Colour Science Concept and Methods, Quantitative Data and Formulae*, New York: Wiley. ISBN 0-471-02106-7.

External links

- Charles Poynton's Color FAQ (http://www.poynton.com/ColorFAQ.html) for the basics.
- Frequently asked questions about Color Physics (http://www.colourware.co.uk/cpfaq.htm) - also includes history of the CIE color specification
- What color is a blackbody? (http://www.vendian.org/mncharity/dir3/blackbody/) - Colorimetrically-calculated blackbody RGB color values and comment
- Color-temperature: visualising blackbody radiation (http://www.techmind.org/colour/coltemp.html) - Blackbody curves for typical lightsources, and colorimetrically-calculated blackbody color strip
- Color Temperature & (CRI) (http://www.nolico.com/saveenergy/color_temperature_and_cri.htm) - Discussion of: Color Temperature (Kelvins) and Color Rendition Index (CRI)

Film- and video-related

- White Balance (http://www.nikondigital.org/articles/white_balance.htm) - Intro at nikondigital.org
- Understanding White Balance (http://www.photoxels.com/tutorial_white-balance.html) - Tutorial
- White Balance (http://www.cambridgeincolour.com/tutorials/white-balance.htm) - Understanding its use

in digital photography

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